United States
Department of
Agriculture

Forest
Service

October 2017

Geology Report

Lovers Canyon Project

Salmon/Scott River Ranger District
Siskiyou County, California

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Geology Report

Introduction

The purpose of this report is to analyze the effects of the project alternatives on landslide rates and groundwater resources.

The Forest Service Manual Chapter 2880 (Geologic Resources, Hazards and Services; USDA 2008) requires the assessment of the risk of loss of life, property and natural resources from both naturally-occurring and management related landslides. The risk must be minimized or mitigated when possible. The Klamath National Forest Land and Resource Management Plan (Forest Plan) directs the interdisciplinary team to manage vegetation on unstable lands to maintain or enhance slope stability (Forest Plan Standard and Guideline 2-1). Project-level review of the unstable lands is required to validate the current mapping (Forest Plan Standard and Guideline 2-2). Unstable lands are defined as active landslides, inner gorges, toe zones of dormant landslides and severely-weathered and dissected granitic lands. These features are considered Riparian Reserves (Forest Plan Standard and Guideline MA 10-2).

Public scoping comments brought forward a concern over the effect of the project activities on spring discharge on private land in the project area (Section 33). This report will analyze the likelihood and estimated magnitude of effects to the spring system of concern.

Methodology

Analysis Indicators

Landslide Risk. The Forest Plan guides projects to manage vegetation on unstable lands to maintain or enhance slope stability. Slope stability can be defined in terms of landslide risk. Landslide risk is the chance of effects of injury or loss as a measure of the probability and adverse consequences to safety, property or natural resources. Landslide likelihood is determined by geomorphic landform, disturbance, landslide modeling, and road density. Debris slide and debris flow processes are most likely to be influenced by the loss of root strength and interception as a result of timber harvest and prescribed burning versus deep-seated landslides which are not as vulnerable to vegetation changes. Deep-seated landslides such as the large dormant landslide features in the project area are not likely to be reactivated as a result of the proposed activities (Benda et al. 2005, Reid 2010 and Slaymaker 2001). Therefore, the focus of the landslide risk assessment is to analyze the indirect effects of the project alternatives on debris slide and debris flow processes.

Project design features are incorporated into the alternatives and are intended to individually and synergistically reduce the effects of the project on resources, human safety, private and public property and essential infrastructure. The focus of this analysis is the watershed project design features because these are the primary mitigations that act to minimize effects of the project on the landslide rate.

Effect to the Spring Flow in Section 33. The effects of the project on the potential for and change in slope stability (which could affect spring flow) are analyzed in the landslide risk indicator. The results will be incorporated into this indicator qualitatively. The most probable effect of timber harvest is an increase in spring flow at least in the short-term (>5 years). The scoping comment for which this indicator was developed is focused on a concern about a reduction in flow to springs on private property. Groundwater science indicates that this is not probable (Hibbert 1967). However, to cover all bases the most probable effect will be analyzed in this report. Vegetation management can change groundwater dynamics. The changes are a result of modifications to the amount of precipitation intercepted by canopy cover, changes to the amount of evapotranspiration, and changes to soil characteristics from compaction. The focus of this analysis will be the likelihood of the silvicultural prescriptions and logging methods to lead to measurable change in spring discharge. Also, if the changes are measurable the magnitude of the change will be estimated.

Measures

Landslide Risk

The forest-wide goal is to promote slope stability and maintain soil productivity on geologically unstable lands (Forest Plan, page 4-5). Slope stability is indirectly affected by many land management practices. However, it is difficult to directly measure slope stability due to the stochastic (random) and complex nature of landslide processes in the Klamath Mountains. This analysis uses landslide risk as a proxy for slope stability. Landslide risk is a combination of the likelihood a landslide event may occur and the consequences of such an event.

Landsliding Likelihood

Landslide likelihood is determined by geomorphic landform, disturbance, vegetation condition, bedrock type, and groundwater conditions. The analysis uses existing geomorphic mapping, bedrock mapping and historical landslide information to determine the likelihood of landsliding. A majority of the west side of the Forest is relatively unstable so the likelihood of having small localized landslides in any given 7th field watershed during any storm is highly probable. This analysis is focused on determining the likelihood of a *landslide event*. A landslide event is defined for this analysis as large-scale, extensive episode resulting in several landslides that could interrupt ingress/egress, fluvial processes on 3th to 5th order streams or damage major infrastructure across a 7th field watershed. (Dai et al. 2002, Wise et al. 2004 and AGS 2007)

The likelihood of a landsliding event was analyzed at the 7th field watershed scale using a combination of the percent the watershed harvested or burned within the last 10 years, CWE GEO risk ratio, percent of unstable lands. The likelihood categories are summarized below:

1) Almost Certain – a landsliding event is expected to occur even under an average storm event (2-year storm event). A watershed in this category meets at least **two** of the following criteria: 1) greater than or equal to 25% of the watershed had high to moderate disturbance (based on soil burn severity, silviculture or fuels reduction prescriptions) in the past 10 years; 2) CWE GEO risk ratio greater than or equal to 1.5; or 3) greater than or equal to 25% of area designated as unstable lands (per definition in Forest Plan)

2) Highly Likely – A landsliding event will probably occur under an average storm event. A watershed in this category meets at least **one** of the following criteria: 1) greater than or equal to 25% of the watershed had high to moderate disturbance (based on soil burn severity, silviculture or fuels reduction prescriptions) in the past 10 years; 2) CWE GEO risk ratio is greater than 0.95; or 3) greater than or equal to 25% of the area is designated as unstable lands.

3) Likely – A landsliding event is likely to occur under a 10- to 20-year storm event. A watershed in this category meets at least **one** of the following criteria: 1) between 10% and 25% of the watershed had high to moderate severity disturbance (based on soil burn severity, silviculture or fuels reduction prescriptions) in the past 10 years; 2) CWE GEO risk ratio is between 0.75 and 0.95; or 3) between 10% and 25% of the area is designated as unstable lands.

4) Unlikely – Landsliding might occur under a 20- to 99-year storm event. A watershed in this category meets if it is on the west side of the Forest and does not meet the criteria in above categories.

5) Rare – Landsliding is conceivable but only under a ≥100-year storm event. A watershed meets this category if it is on the east side of the Forest (with occasional exceptions).

Consequence Categories

The consequences of a landslide are based on the impacts to elements at risk. The elements at risk for this analysis are human safety, infrastructure, property, recreation/visitor use and environmental resources. The consequences categories are summarized below:

1. Catastrophic Consequences– In this category human health and safety is susceptible to landslide events. The presence of occupied structures (homes, businesses, work areas), campgrounds, or heavily used roads that are vulnerable to (in the path of) a potential landslide event meets the criteria for this category.

2. Major Consequences – In this category essential infrastructure such as main National Forest Transportation System (system) roads (maintenance levels 3, 4 and 5), power lines, pipelines, municipal water sources, and railroads is susceptible to (in the path of) landslide events and may be rendered inoperative as a result. The category also is used to

describe vulnerability of anadromous fish habitat to landslide events that lead to the complete loss of the habitat. This category also applies when stream channels are vulnerable to landsliding which leads to aggrading (depositing sediment) or degrading (removing sediment) the stream channel. Also, the reduction of shade and riparian vegetation over a large portion of late flowing intermittent or perennial streams is a major consequence.

3. Moderate Consequences – In this category only non-essential infrastructure and property such campgrounds (unoccupied), trailheads, day use areas and system trails are vulnerable to landslide events and will be rendered inoperable. Landsliding debris will temporarily block major ingress/egress roadways. Anadromous fish habitat is vulnerable to a partial loss or short-term impairment. This category also applies when stream channels are vulnerable to aggradation, degradation or a reduction shade over a small portion of late-flowing intermittent and perennial streams.

4. Minor Consequences – In this category infrastructure is vulnerable to damage that does not render it inoperable but makes its operation unsafe or inconvenient (e.g. debris partially blocking a two-lane road) as a result of landslide events. The minor damage category applies to landsliding into streams that are vulnerable to a reduction of shade at the site scale or blocking the stream for the short term (<6 months).

5. Nuisance Consequences – In this category there is no infrastructure, fish habitat or stream shade vulnerable to landslide events.

Landslide Risk Matrix

The landslide risk matrix (Table 1) is the cross-walk between the likelihood and consequences and the implications for Forest management. Once the likelihood and consequences have been determined using the criteria above, the risk matrix is used to determine the risk category that fits that situation. For instance, you may have an area that is likely to experience landsliding during a 10-year storm event and the essential infrastructure vulnerable to landsliding. In this case the landslide risk is high. This risk has implications for Forest management which are described in the section below.

Table 1: Risk matrix using likelihood and consequence to assess risk of a landslide event in a 7th field watershed.

Consequences/Likelihood	**Almost Certain**	**Highly likely**	**Likely**	**Unlikely**	**Rare**
Catastrophic Consequences	Very High	Very High	High	Moderate	Moderate

Major Consequences	Very High	High	High	Moderate	Low
Moderate Consequences	High	High	Moderate	Moderate	Very Low
Minor Consequences	High	Moderate	Low	Low	Very Low
Nuisance Consequences	Low	Low	Very Low	Very Low	Very Low

The Risk Category Implications

1. Very High – Health and human safety or essential infrastructure is at risk. There is an immediate and urgent need to reduce the likelihood of landsliding or mitigate the consequence to the elements at risk.
2. High – There is a reasonable probability that landsliding will impact essential infrastructure and may impact health and human safety. Non-essential infrastructure as well as recreation and visitor use may be impacted. Project-wide and global mitigations need to be in place to minimize impacts to landslide processes for actions in these watersheds.
3. Moderate - There is a moderate probability of impacts to essential or non-essential infrastructure or health and human safety as a result of landsliding. The cost and benefit of mitigations needs to be considered before actions are proposed for implementation. Strategic or localized mitigations need to be in place to minimize impacts to landslide processes for actions in these watersheds.
4. Low – There a low probability of impacts to elements at risk. Remediation of landsliding consequences may be the most cost effective method of dealing with these areas.
5. Very Low – There is almost no probability of impacts to elements at risk as a result of landsliding. Mitigations are rarely needed.

Design Feature Effectiveness in Minimizing Landslide Risk

The project has three primary potential effects on landslide processes which are mitigated through the implementation of project design features (see Chapter 2 of the EA). Project design features designed to protect watershed resources are intended to be the on-the-ground measures that implement Best Management Practices. First, there is the potential for disturbance of unstable lands either directly or indirectly. Unstable lands (active landslides, toe zones of dormant landslides, steep granitic lands, and inner gorges) are sensitive to direct disturbance from heavy equipment such as skidders and tractors. Indirect disturbance includes a change in the mass balance of the hillslope by cutting into the hillslope to build a road, adding fill to the outside of a roadbed to widen it, or adding weight to the top of a landslide. The last example is most likely to occur as a result of landing construction or road building.

Second, vegetation management projects have the potential to change the hydrology of the hillslope. The actions may increase the amount of surface runoff and how surface water is routed over the hillslope. These changes can increase landslide rates by causing rilling and gullying on the hillslope, undercutting the hillslope and increasing the flow in stream channels making debris flows more probable. Removing vegetation using skidding and yarding techniques especially on steep slopes can increase the rilling and gullying. Poorly designed roadbeds can also concentrate water on the hillslope. Vegetation projects have the potential to increase peak flows via new road construction, landing construction, soil compaction and changing interception and evaporation of precipitation. The change in interception and evapotranspiration by trees can also lead to an increase in groundwater tables which can decrease the stability of the hillslope especially in swales.

The final potential effect is the reduction in root support which can lead to hillslope instability. The roots of forest vegetation, especially trees, help stabilize slopes by providing additional strength to the soil (Ziemer 1981; Ziemer and Swanston 1977; Ammann et al. 2009). Once trees are killed, even their largest roots start to decay and lose strength within a decade (Ziemer and Swanston 1977).

There are three components to design feature effectiveness. First is the scale of reduction or how large is the effect of the project design feature. This analysis breaks the scale into site scale and 7th field watershed scale. The second component is the duration of the reduction in effects compared to the duration of project effects (i.e. shorter than, equal to or longer than). The third is the reliability of the project design feature. This analysis uses the Best Management Practices Evaluation Program results to determine the reliability of the implementation and the effectiveness of reducing effects. These two were combined to create an index of high, limited and low reliability.

To this end, this analysis will group design features into three categories, 1) Avoidance of unstable lands, 2) Changes to probability of hillslope hydrology modification, and 3) Changes to root strength.

The effectiveness of the mitigations will be categorized as:

- *Extremely Effective*: This indicates that the mitigation is expected to eliminate all effects of the project activity on landslide rates at the watershed and site scales.
- *Highly Effective:* This indicates that the mitigation is expected to reduce the effects on landslide rates at the site and watershed scale to below any measurable level.
- *Moderately Effective:* This indicates that the mitigation is expected to reduce the effects of the project on landslide rates to below measurable at the watershed scale but effects may be seen at the site scale.

- *Marginally Effective:* This indicates that the mitigation has does little to reduce the project's effect on landslide rate at either the watershed or site scale.
- *Ineffective:* This indicates that the mitigation does not reduce the project's effect on landslide rate.

If the project design features have been shown to have a low reliability the effectiveness is considered marginal for all scale and duration categories. If the duration of effectiveness is less than the expected effects of the project the effectiveness is considered marginal for all scale and duration categories. If the effectiveness is only at the site scale, has duration greater than or equal to the project effects and have a moderate or high reliability the effectiveness is moderate. If the effectiveness is at the watershed scale, has a duration that is equal to the effects of the project and a moderate reliability the effectiveness is moderate. If the effectiveness is at the watershed scale, has a duration that is equal to the effects of the project and a high reliability the effectiveness is high. . If the effectiveness is at the watershed scale, has a duration that is greater than the effects of the project and a moderate reliability the effectiveness is high. If the effectiveness is at the watershed scale, has a duration that is greater than the effects of the project and a high reliability the effectiveness is extremely high. This is outlined in a decision tree in Appendix B.

Effect to the Spring Flow in Section 33

As discussed above, the deep-seated dormant landslides are not likely to be sensitive to the proposed activities (Benda et al. 2005, Reid 2010 and Slaymaker 2001). A wholesale movement of the dormant feature that would affect the spring complex as a result of this project is not probable. The focus of this analysis is the changes to the springs that may occur as a result of the loss of canopy, precipitation interception changes and modification of the evapotranspiration rates.

John Stednick (1996) in his summary of timber harvest effects on groundwater literature found that changes of less than 20% basal area in a catchment did not, on average, produce measurable changes in water yield. He also describes a nation-wide average of the relationship between timber harvest and water yield for areas with more than 20% of the basal area removed. The relationship is that for every 1% of basal area removed the water yield increases by about 2.5 mm.

The amount of basal area removed from the catchment basin will be estimated using the silvicultural prescriptions for each treatment unit. It will be assumed that in areas with no proposed treatment there will be a zero percent change to the basal area. It is assumed that will be nearly no basal area removed as a result of underburning. The pre-commercial harvest and fuel breaks are assumed to remove about 10% of the total basal area and commercial harvest units will have no more than an average of 30% basal area removed. The total basal area removed from the catchment will be calculated using a weighted percent calculation. If an alternative proposes more treatments that lead to more than 20% of the basal area removed in the catchment the magnitude of the change will be estimated using the relationship described above.

Spatial and Temporal Bounding of Analysis Area

The spatial scale for landslide risk is the 7th field watershed scale for the direct/indirect effects and the cumulative effects. The models used for analysis are calibrated at a 7th field scale (Bell 2012). The temporal scale is 0-10 years for short-term and >10 years for long-term. Elevated landslide rates due to forest management have been shown to begin to decrease around 7-12 years after the disturbance in Northern California (Ziemer 1981).

The spatial scale for the effects to the spring system in Section 33 is the catchment immediately above the spring complex (Figure 2). The catchment is the area that is most likely to contain the area of groundwater recharge (where the water enters the ground) for the spring complex. Stednick (1996) found that the maximum measured change in groundwater studies analyzing the effects of timber harvest was between 1 and 5 years after the treatment. With this in mind the temporal bound for this analysis is 5 years.

Affected Environment

Landslide Risk

The current landslide likelihood includes the effects on landslide rate from the 2014 wildfires (Figure 1). Deep Creek has a very likely landslide likelihood. This means that the watershed is likely to experience a landsliding event during an average storm event. This is elevated of a combination of effects from the 2014 wildfires and the legacy of private land harvest. Isinglass, North Fork Kelsey, South Fork Kelsey, Boulder and Lower Canyon Creeks have are likely to have a landsliding event if a 10-20 year storm event should occur in the watershed. Upper Canyon is not likely to experience a landsliding event unless there is a greater than 20 year storm event which has less than a 5% chance of occurring in any given year. The high precipitation that occurred during the winter of 2016-2017 resulted in 17 new landslides in the project area, totaling 29.1 acres. However, only three of the seven watersheds were affected; Isinglass Creek – Scott River (2.6 acres), Deep Creek- Scott River (2.7 acres), and Lower Canyon Creek (23.8 acres). The model outputs given in Table 2 have been updated to reflect the changes in background conditions due to these recent events.

Table 2: Landslide likelihood under current conditions for the analysis watersheds.

Watershed Code	Watershed Name	Existing CWE-GEO model Risk Ratio	Unstable Lands (% Watershed)	Watershed Disturbance (% Watershed)	Landslide Likelihood
18010208060402	Deep Creek-Scott River	1.37	17%	10%	Highly Likely
18010208060203	Isinglass Creek-Scott River	0.75	17%	1%	Likely
18010208060301	North Fork Kelsey Creek	0.39	12%	18%	Likely
18010208060302	South Fork Kelsey Creek	0.30	10%	3%	Likely

18010208060202	Boulder Creek	0.11	10%	0%	Likely
18010208060103	Lower Canyon Creek	0.37	14%	4%	Likely
18010208060101	Upper Canyon Creek	0.06	5%	3%	Unlikely

The consequences of a landsliding event in Deep Creek include potential effects to Coho critical habitat. Past debris flows have blocked the mouth of the creek, reduced shade along creek and aggraded or degraded the stream channel. The Scott River Road crosses Deep Creek via a bridge which is designed to pass a debris flow. The Deep Creek watershed sustained three landslides during the winter of 2016-2017, two of which are earth flows and the other a debris slide. The debris slide is the only feature that contributed sediment to the Scott River (appendix B). The main consequence of landsliding in Deep Creek is to fish habitat which constitutes a moderate consequence.

Isinglass Creek 7th field watershed straddles the Scott River, so it includes Coho critical habitat. During the winter of 2016-2017, two landslides occurred within the watershed affecting 0.15 acres of prescribed units. One is a large earthflow that had very little movement and did not deliver any sediment to Scott River. The other, a small debris flow that distributed sediment on to the flood plain below, but did not directly deposit sediment into the Scott River. Neither of these events reduced shade in the tributaries, and the consequences of these landslide events in this watershed remains minor.

Portions of the main stem of North Fork and South Fork Kelsey Creek contains Coho critical habitat. Past landslide events have triggered debris flows in this watershed which have reduced shade along the creek, aggraded and degraded the stream channel. The consequences of a landsliding event will be moderate.

Boulder Creek is used for a domestic water supply and has occupied private land at its mouth. The road on private land that crosses Boulder Creek could also be used as a secondary ingress/egress route during and emergency for the private land owners. Past landslide events have damaged both, so the consequence of a landslide event is major for this watershed.

Upper and Lower Canyon Creek has had small debris flows in face drainage tributaries to the main stem of Canyon Creek, but there was little to no evidence of channel alteration in the channels in the aerial photos. However, 10 landslides did occur during the 2016-2017 winter. The majority of these are earthflows, contributing no sediment to Canyon Creek. Three of these were debris flows of which only two contributed sediment to Canyon Creek. The shade removal was minimal and the sediment delivered is not likely to have any long-term effect on fish habitat in the main stem (appendix B of the Lover's Canyon Project Environmental Assessment). The consequence of a landslide event remains minor.

The landslide risk is high for Deep Creek and Boulder Creek. North and South Fork Kelsey Creek have moderate landslide risks. Isinglass Creek, Upper Canyon Creek and Lower Canyon Creek have low landslide risks under current conditions (Table 3).

Table 3: Landslide risk under current conditions for analysis watersheds.

Watershed Code	Watershed Name	Likelihood	Consequence	Risk
18010208060402	Deep Creek-Scott River	Highly Likely	Moderate	High
18010208060203	Isinglass Creek-Scott River	Likely	Minor	Low
18010208060301	North Fork Kelsey Creek	Likely	Moderate	Moderate
18010208060302	South Fork Kelsey Creek	Likely	Moderate	Moderate
18010208060202	Boulder Creek	Likely	Major	High
18010208060103	Lower Canyon Creek	Likely	Minor	Low
18010208060101	Upper Canyon Creek	Unlikely	Minor	Low

Spring Flow in Section 33

The groundwater recharge area, or catchment area, for a spring or a complex of springs is difficult to determine exactly. This analysis is using a conceptual groundwater model described by J. Toth (1963). This is a standard model to use when the groundwater system is not completely understood. The "Tothian" groundwater model assumes that the groundwater tables follow the surface topography. So the groundwater is recharged uphill and discharged into springs or stream beds downhill. This occurs at local, intermediate and regional scales. This analysis is only concerned with the local scale (<300 feet below the surface).

Using this model catchment for the springs in section 33 is about 885 acres (Figure 2). Precipitation falls on the upper portion of the catchment enters the groundwater. Then the groundwater flows downhill where it is discharged from the groundwater at springs.

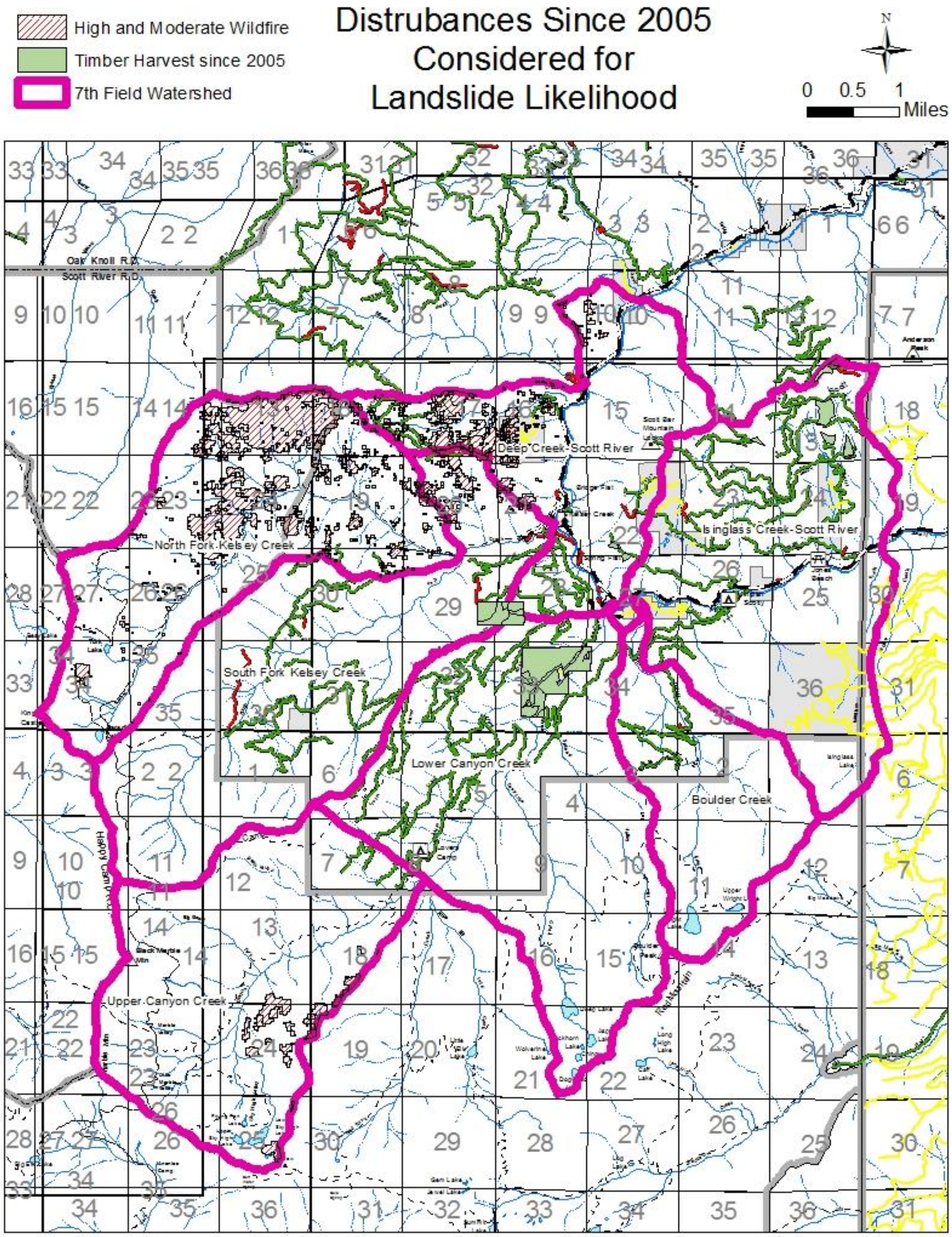

Figure 1: Map of timber harvest and areas with high and moderate wildfire severity in the analysis watershed between 2005 and 2015.

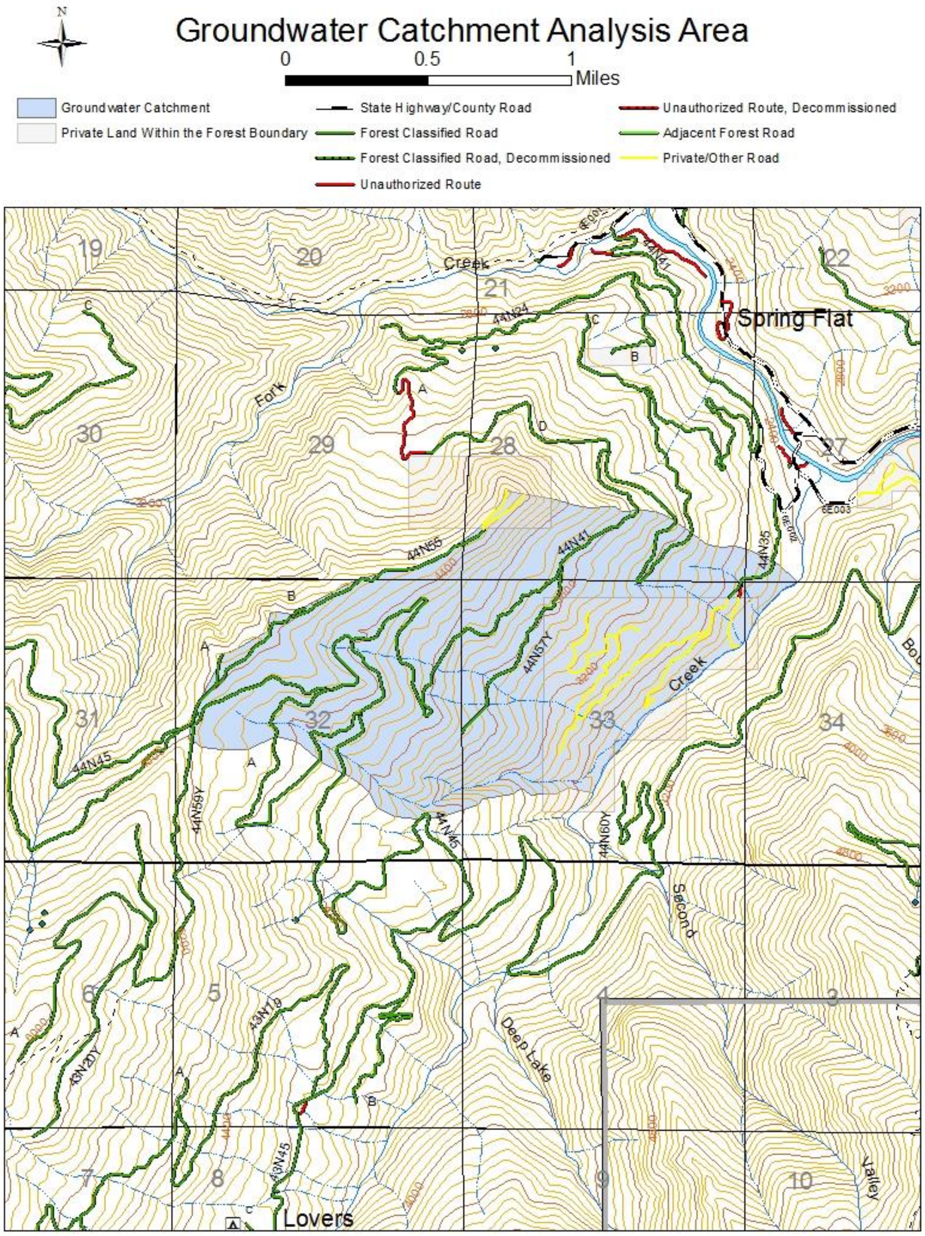

Figure 2: Map of the spatial bounds of the analysis area for the Likelihood of Effects to the Springs in Section 33 analysis.

Environmental Consequences

Alternative 1 – No Action

Direct Effects and Indirect Effects

<u>*Landslide Risk*</u>

Under this alternative no management action will be taken. There are no direct or indirect effects to landslide rates.

Effects to Spring Flow in Section 33

There will be no immediate change in vegetation as a result of this alternative so there is no short term effect to the spring flow. Any long term effects that may result due to tree mortality due to poor stand health will be gradual and difficult to discern from the natural variation of spring flow from year to year.

Cumulative Effects

Landslide Risk

There are no direct or indirect effects to the landslide risk so there are no cumulative effects to landslide risk.

Effects to Spring Flow in Section 33

There are no direct or indirect effects to spring flow from alternative 1 so there are no cumulative effects.

Effects Common to Alternative 2 and Alternative 3

For effects to geology resources there will be no measurable differences to the analysis indicators between alternatives 2 and 3 and these alternatives will be discussed together. Alternative 3 has more skip areas incorporated into a set of units than alternative 2, this difference will account for less total ground disturbance within these units, however, the difference is not enough to change the effect that the proposed treatments will have on the measure of the geology analysis indicators because the overall footprint of disturbance is the same between these alternatives.

Direct and Indirect Effects

Landslide Risk

Of all the landslides that occurred in the winter of 2016-2017 in the project area, only 10 affected prescribed treatment units totaling 14.9 acres. The model has been updated to reflect these changes in background conditions. Both action alternatives increase the risk ratio for Deep Creek – Scott River from 1.37 to 1.40. It also increases Lower Canyon Creek form 0.37 to 0.44 and South Fork Kelsey Creek from 0.30 to 0.31. The 2016-2017 winter events increased the Isinglass Creek-Scott River from 0.12 to 0.75. Even with the change in background conditions, the result is still under the threshold of concern, and the change was not enough to alter the risk rating (Appendix A and Table 4). The Cumulative Watershed Effects model does not take into account the effects of the project design features that are incorporated into the alternative. In the section below the effectiveness in reducing the effects of the alternative area discussed in detail. The project design features synergistically have a high probability of minimizing the risk of landsliding that may occur as a result of the alternative. This means that it is likely that the increase in volume predicted by the GEO model will be offset by the project design features. Concerning the 2016-2017 winter landslides, modifications were made to the project design in order to limit the likelihood of future slope failure due to implementation. There will be no timber harvest or equipment operation within any of the new landslide features that were identified after the winter of 2016-2017 (see appendix B of the Lover's Canyon Project EA for details).

The percent of the watershed with high or moderate disturbance did not change for any of the watersheds (Table 4). The only disturbance that met the criteria were new landing construction and new temporary road construction which represents a small area in the watersheds. There is no measurable change in the landslide risk as a result of alternative 2 and landslide risk will remain the same as described in the Affected Environment section above.

Table 4: Landslide likelihood for each 7th field watershed for alternative 2 and alternative 3.

Watershed Code	Watershed Name	Alt. 2 or Alt. 3 CWE-GEO model Risk Ratio	Unstable Lands (% Watershed)	Watershed Disturbance (% Watershed)	Landslide Likelihood
18010208060402	Deep Creek-Scott River	1.40	17%	10%	Highly Likely
18010208060203	Isinglass Creek-Scott River	0.75	17%	1%	Likely
18010208060301	North Fork Kelsey Creek	0.39	12%	18%	Likely
18010208060302	South Fork Kelsey Creek	0.31	10%	3%	Likely
18010208060202	Boulder Creek	0.11	10%	0%	Likely
18010208060103	Lower Canyon Creek	0.44	14%	4%	Likely
18010208060101	Upper Canyon Creek	0.06	5%	3%	Unlikely

An analysis of the effectiveness of each project design feature that reduce the effects to unstable lands are in Table 7, Table 8 and Table 9 in Appendix C of this report.

Avoidance of Unstable Lands

Chatwin (1994) states that the avoidance of unstable lands is the most effective and cost-efficient method of managing landslide-prone terrain. There are six project design features that provide protection of unstable lands from mechanical equipment. Three of the design features have an extremely high effectiveness and three have a moderate effectiveness. The moderate effectiveness project design features are in that category because they only reduce the effects at the site scale. The overall effectiveness of the project design features to avoid unstable lands is high.

Changes to Hillslope Hydrology

Chatwin (1994) found scheduling activities that the use of wet weather operation standards and normal operating seasons was effective at reducing changes to hillslope hydrology especially rilling/gullying which will indirectly minimize effects to landslide risk. Cristan et al (2016) concluded that roads, skid trails and stream crossings have the highest impact on hillslope hydrology changes in including rilling and gullying. These activities should be given the most attention while planning best management practices for timber harvest in order to be effective in reducing effects.

Madej et al (2012) found that most sediment delivered to the streams in Panther Creek basin (Northwestern California) was from landslides originating on landings and roadbeds. This rate was reduced by improved road and landing construction standards, reduced ground disturbance from tractors for groundbased harvest and treating legacy sediment sources. Litschert and MacDonald (2009) found that using Best Management Practices meant only 19 of 200 sites that had undergone timber harvest had rills or gullies in the Sierra Nevada Forest Service Lands. They attributed this low rate to the installation of effective waterbars on skid trails and properly closing skid trails after completion.

There are twenty-two project design features that are intended to reduce the probability of hillslope hydrology changes. Ten of the project design features have a moderate effectiveness on reducing hydrologic changes. They are all in this category because they are only effective at the site scale. Ten of the project design features have a high effectiveness and two have an extremely high effectiveness. The two in the extremely high effectiveness category include waterbarring skid trails and implementing the wet weather operational standards. The overall effectiveness of the project design features to minimize the effects to hillslope hydrology as related to landslide risk is high.

Changes to Root Strength

The protection of Riparian Reserves including unstable lands, swales in combination with partial harvest techniques that leave some understory vegetation intact have been found to substantially reduce the increase in landslide probability after timber harvest (Sidle 1992; Dhakal and Sidle 2003). Sidle (1992) found that partial cuts that retain the integrity of the understory vegetation maintain enough root strength to balance stand health needs and slope stability concerns. Cristan et al (2016) concluded that implementation of Best Management Practices were most effective in reducing effects to watershed processes when implemented both during treatment activities and at the close of the project.

There are three project design features that minimize the effects to root strength and two project design components. The project design components include the silvicultural prescriptions and the prescribed fire prescriptions (See Chapter 2 of the EA for details). The silvicultural prescriptions are essentially a thin from below and the prescribed fire is intended to be low to moderate severity in a mosaic pattern. Two of the project design features have a high effectiveness in maintaining root support and one has an extremely high effectiveness. The extremely high effectiveness includes restrictions on how much of a watershed can be burned in a given year. This will allow for brush recovery in the watershed between burns. The silvicultural and burning prescriptions will have an extremely high effectiveness of maintaining sufficient root support across the watershed. The overall effectiveness of project design to maintain sufficient root strength for slope stability is extremely high.

Effects to Spring Flow in Section 33

The catchment is 885 acres. About 58% of the catchment will receive underburn only or no treatment is planned. Thirteen percent of the catchment has pre-commercial thinning or fuel breaks proposed and 29% of the catchment has commercial harvest proposed. The weighted area calculation finds that there will be about 10% of the total basal area removed from the catchment (Eq. 1).

% basal area removed = [((13% x 885) x 10%) + ((29% x 885) x 30%)] / 885 = 10%   (Eq. 1)

This is less than the 20% basal area removed described in the methods section as the trigger for measurable effects to spring flow in the catchment. It is unlikely that the project will measurably affect the spring flow in the catchment.

Cumulative Effects

Landslide Risk

There is no effect to landslide risk from grazing activities. Grazing does not change the hillslope hydrology or modify tree root strength. There is also no effect to landslide risk from the renewal of the special use permits. Any effects of the Scott Bar Mountain Under and Habitat Improvement Project were considered the Affected Environment because the Cumulative Watershed Effects Model protocol models all actions with a signed decision as a current action.

The Westside Fire Recovery project overlaps with the project area in the North Fork Kelsey Creek, South Fork Kelsey Creek and Deep Creek-Scott River watersheds. There is about 25 acres, 30 acres and 345 acres of fuels, vegetation and roadside treatments in the North Fork Kelsey, South Fork Kelsey and Deep Creeks respectively. The project focuses on removing fire-killed or fire injured trees which does not have an effect on landslide risk. The actions that are proposed in Westside Fire Recovery that do have an effect on landslide risk are landing construction and new temporary roads. There is landing construction in Deep Creek which is why it is the only watershed that has modeled cumulative effects (see Appendix A). The increase in landslide volume is not enough to increase the risk ratio compared to the direct and indirect effects of alternative 2.

The landing construction in Deep Creek does not increase the percent of the watershed with high or moderate disturbance. The cumulative effects of the Westside Fire Recovery project do not increase the landslide risk. The risk remains the same as described in the Affected Environment above.

Effects to Spring Flow in Section 33

There are no actions considered for cumulative effects that overlap the analysis area for this analysis so there are no cumulative effects.

Summary of Effects

Table 5: Summary of effects on landslide risk, project design feature effectiveness and to spring flow.

Indicator	Alternative 1	Alternative 2 and Alternative 3
Landslide Risk	The landslide risk is high for Deep Creek and Boulder Creek. It is moderate for North and South Fork Kelsey Creeks and low for all of the other watersheds.	The landslide risk is the same as for alternative 1.

Effects to Spring Flow in Section 33	There are not likely to be any acute effects to the spring flow.	There will be about 10% basal area removal on average over the groundwater catchment area. This is below the threshold for measurable changes to spring flow.

Compliance with law, regulation, policy, and the Forest Plan

Existing mapping was field verified by the Forest Geologist and unstable lands were removed from treatment areas were slope stability was not benefited. The landsliding magnitude and risk were analyzed for all of the alternatives in the project. The risk associated with the direct/indirect and cumulative effects of the project have been minimized by project design features.

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Appendix A: CWE model Results

Table 6: The Cumulative Watershed Effects Model results for the GEO Model for Affected Environment, Alterative 2 and the Cumulative Effects.

		Current (Affected Environment)									Indirect Effects Alternative 2					Cumulative Effects	
Drainage Code	Drainage Name	Background Landslide Volume (yd3/decade)	All Past Harvest and Wildfire older than 2014 (yd3/decade)	2014 Wildfire (yd3/decade)	Road System (yd3/decade)	Total Current Landslide Volume (includes background) (yd3/decade)	Percent Landslide Volume contributed to Past Harvest and Older Wildfire	Percent ERA contributed to 2014 Wildfire	Percent Landslide Volume contributed to Road System	Total Current GEO Risk Ratio	Harvest and Prescribed Fire for Alternative 2 (yd3/decade)	New Landing Construction (yd3/decade)	Temporary Roads Alternative 2 (yd3/decade)	Total landslide Volume for Alternative 2 (yd3/decade)	Alternative 2 Risk Ratio	Estimated Landslide Volume from Future Actions (yd3/decade)	Total Cumulative Risk Ratio
18010208060101	Upper Canyon Creek	9868.5	547.3	0	646.4	11062.2	46%	0%	54%	0.06	0	0	0	11062.2	0.06	0	0.06
18010208060103	Lower Canyon Creek	14543.1	1363.2	0	8988.1	24894.4	13%	0%	87%	0.36	1951	10.1	103.2	26958.7	0.43	0	0.43
18010208060202	Boulder Creek	6607.3	64.5	0	1443.7	8115.5	4%	0%	96%	0.11	0	0	0	8115.5	0.11	0	0.11
18010208060203	Isinglass Creek-Scott River	12204.0	1132.1	0	1722.1	15058.2	40%	0%	60%	0.12	3.1	0	1	15062.3	0.12	0	0.12
18010208060301	North Fork Kelsey Creek	9389.5	1.4	6671.8	559	16621.7	0%	92%	8%	0.39	0	0	0	16621.7	0.39	0	0.39
18010208060302	South Fork Kelsey Creek	19415.0	313.3	3734.5	7578.5	31041.3	3%	32%	65%	0.30	313.8	0	0	31355.1	0.31	0	0.31
18010208060402	Deep Creek-Scott River	7955.3	225.3	5035.3	16469.7	29685.6	1%	23%	76%	1.37	468.3	5.8	16.4	30176.1	1.40	36	1.40

Appendix B: Project Design Feature Effectiveness Decision Tree

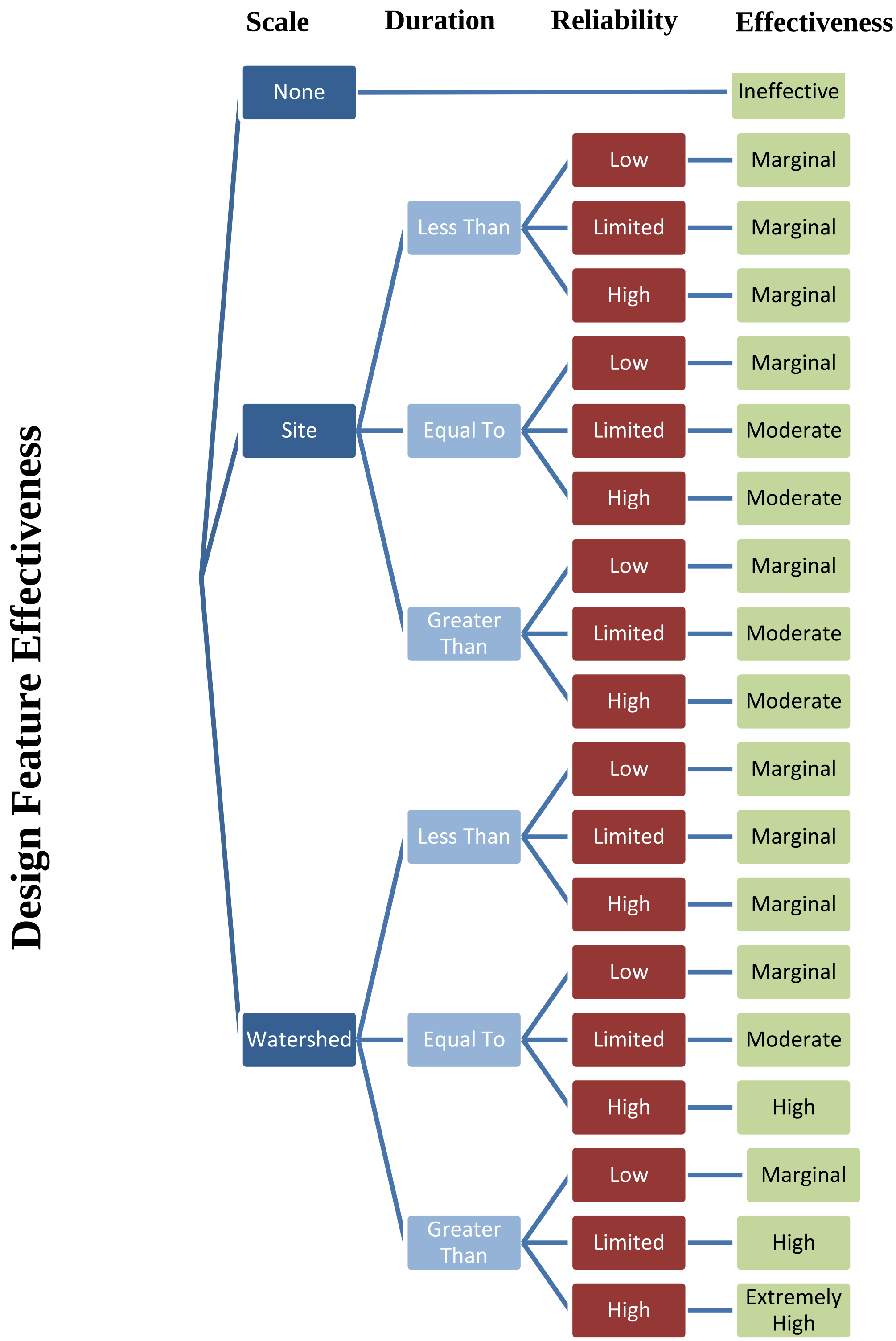

Figure 3: Project Design Feature effectiveness decision tree.

Appendix C: Project Design Feature Effectiveness Analysis Matrix

Table 7: Project design feature effectiveness for unstable lands avoidance.

Project Design Features (as labeled in Chapter 2 of EA)	Scale of Effectiveness	Duration of Effectiveness	Reliability of Design Feature	Effectiveness
WS-3	Watershed	Greater Than	High	Extremely High
WS-4	Watershed	Greater Than	High	Extremely High
WS-7	Watershed	Greater Than	High	Extremely High
WS-8	Site	Greater Than	High	Moderate
WS-18	Site	Greater Than	High	Moderate
WS-27	Site	Greater Than	High	Moderate

Table 8: Project design feature effectiveness for changes to probability of hillslope hydrology modification.

Project Design Features (as labeled in Chapter 2 of EA)	Scale of Effectiveness	Duration of Effectiveness	Reliability of Design Feature	Effectiveness
WS-5	Watershed	Greater Than	Limited	High
WS-6	Watershed	Greater Than	Limited	High
WS-8	Watershed	Greater Than	Limited	High
WS-11	Watershed	Greater Than	Limited	High
WS-12	Site	Greater Than	High	Moderate
WS-14	Watershed	Greater Than	Limited	High
WS-17	Watershed	Greater Than	Limited	High

WS-18	Site	Greater Than	High	Moderate
WS-19	Site	Greater Than	High	Moderate
WS-21	Watershed	Greater Than	High	Extremely High
WS-20	Site	Greater Than	High	Moderate
WS-27	Site	Greater Than	High	Moderate
WS-35	Site	Greater Than	High	Moderate
WS-43	Watershed	Greater Than	Limited	Moderate
WS-44	Watershed	Greater Than	Limited	High
ENG-1	Site	Greater Than	High	Moderate
ENG-2	Site	Greater Than	High	Moderate

Table 9: Project design feature effectiveness for changes to root strength.

Project Design Features (as labeled in Chapter 2 of EA)	Scale of Effectiveness	Duration of Effectiveness	Reliability of Design Feature	Effectiveness
Silvicultural Prescriptions	Watershed	Greater Than	High	Extremely High
Prescribed Fire Prescriptions	Watershed	Greater Than	High	Extremely High
WS-53	Watershed	Greater Than	Limited	High
WILD-6	Watershed	Greater Than	High	Extremely High
WILD-20	Watershed	Greater Than	Limited	High